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HIGHLIGHTS

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* RESEARCH REQUIREMENTS -- HIGH PERFORMANCE SHIPS

The U. S. Navy is currently engaged in the study of a variety of design concepts for high performance ships, some of which differ sharply from conventional forms. In addition, this program is bringing into maritime research and development many organizations in industry and university laboratories which have no previous background in maritime R&D -- the aircraft industry is a notable example.

Since many of these programs are still in the earliest stages of design and development, a number of research opportunities exist for organizations interested in using their specialized capabilities in these new fields. Here is a summary of current research requirements in the field of high-performance ships, derived from an analysis prepared by D. L. Silverstein, Office of Naval Research and O. H. Oakley, Bureau of Ships, U. S. Navy, Washington 25, D. C.

Ground-Effect Machines

Ground effect craft, which operate on a cushion of air, offer the contradictory capabilities of high speed, and the ability to hover above the surface. Speeds of well over 100 knots appear to be attainable. Recent evidence indicates that in the high speed range of operation these craft will not respond to wave action, but can maintain level flight over ocean waves. This, plus the hovering capability, indicate potential applications for amphibious warfare, anti-submarine warfare, aircraft carriers, missile carriers, cargo and personnel carriers, etc.

Some problems:

✓ Structures: A major problem is how to design the light structure required, while still retaining the ability to land and rest on the water in waves. Aircraft structures would be too light to meet the landing in waves requirement, while standard ship structures would be so heavy as to eliminate any payload. A "blending" is required.

✓ Stability and Control: Behavior over waves is not well understood. Tests to date indicate problems associated with running trim even in calm water. Theoretical insight is being gained into the mechanisms of damping and resonant frequencies of motions over waves, but this is not complete, and there is not much experimental experience.

✓ Scaling Laws: Being carefully examined, especially in light of British experiments with their "Hovercraft." In this vehicle, large scale tests indicated severe spray problems which did not arise in small scale model tests.

✓ Air Fans: Light weight, high capacity air fans are required that will operate against high cushion pressure. It is estimated that for large, operational ships this back pressure may be in the order of 151 pounds per square foot. Such fans "are not shelf items."

(Continued)

Ground Effect Machine Problems (Continued)

✓ Ram-Wing: One of the advanced ground effect designs is a so-called "ram wing" model, actually a low-flying aircraft. Significant reduction in induced drag, achieved by flying close to the surface, should permit the attainment of very high lift/drag ratios at high speeds. However, the ram-wing will also encounter all of the problems of take-off, landing and in-flight control of ordinary aircraft, plus the precise control required in flying close to the surface. Take-off or low speed power requirements may well prove to be governing.

✓ Water-Curtain: In some ground effect designs a water curtain provides the seal to contain the cushioning air. The dynamics of water-wall craft have not been examined extensively. One problem is the reduction of air "leakage" through the water screen. The screen is relatively good at short distances down from the jet exit, but, leakage is severe at substantial heights before the jet hits the free surface.

Conclusion: "From the designer's viewpoint, the promises are meaningful and the problems do not appear insurmountable. However, a considerable expenditure of research effort and time are required. U. S. Navy work in this field is aimed at the construction of a large ground effect vehicle about 1963. The size and type await the results of research now underway."

Submarines

Within the past 10 years technological advances have been exploited to make the submarine the most mobile and powerful warship yet devised. However, problems in improving performance still exist.

One of these problems:

✓ Increased Speed: The most direct way would be to simply increase power. This will require a larger hull, and would mean that some of the gain is lost through added frictional resistance. One study, holding payload constant and using specific weights and volumes for machinery, indicates that a submarine would require well over 100,000 shaft horsepower to attain 50 knots -- right at the bounds of present technology as regards the power that can be absorbed by a single propeller. Other methods of improvements, such as reduction of resistance by boundary layer control, appear elsewhere in this report.

Near-Surface Craft

This craft is intended to combine the stealth, speed and motion action characteristics of the modern submarine with the air-breathing, air-communication aspects of the surface ship. At present, it is explained, nuclear power plant weights are extremely high compared with the more advanced air breathing plant. If the submarine could be run sufficiently close to the surface to breathe air through a slender strut, and still stay far enough down to avoid excessive wave drag, a light weight, air-breathing plant could be used. In order to compete with a destroyer hull form of equal displacement, the near-surface craft must travel below a depth of about one and a half diameters to the axis. This implies a strut length somewhat greater than one hull diameter, plus additional length in order to project some distance above the free surface to allow for waves and depth control variations. Such a strut must carry at least a periscope or closed circuit TV camera unit, communications and radar antenna and a snorkel head valve. The size of the air passages required appears to govern the size of the strut. It may have to be so large that it would degrade the speed performance and affect the stability and control. Submarine-type controls would be required -- in fact would have to be more effective to counter the effects of surface waves. Also, the structure would have to be sufficiently strong to withstand accidental deep submergences.

Hydrofoil Craft

Hydrofoil craft promise primarily high speeds -- possibly more than 100 knots. In addition, motions in a seaway should be considerably less than buoyant craft of the same displacement. These craft can maintain high speed in sea conditions considerably more severe than would compel a conventional craft to slow down. The U. S. Navy has maintained a hydrofoil program since shortly after World War II, and a large antisubmarine hydrofoil craft "PC (H)" contract was recently awarded to the Boeing Airplane Co.

Among problems to be solved:

✓ Hydroelastic Dangers: The determination of flutter and divergence is a major problem. There is no adequate theory for prediction of instability speeds, and practically no experimental work in the marine range of interest. The flow problems at the intersection of strut, foil and nacelle require attention. Flap effectiveness at low submergences appears to be less than predicted by theory.

✓ Flying Qualities: In very high speed hydrofoil craft, of 70 to 100 knots, the frequency of encounter with waves will be so high that it will be impossible to "contour" the surface without inducing excessive accelerations. This implies the necessity for "platforming" -- that is the craft's trajectory must remain essentially horizontal. This further implies submerged foils as a requirement, because surface-piercing systems cannot platform. In addition, long struts will be needed to keep the hull clear of the water, and yet insure continuous good submergence for the foils in rough water. In order to platform, the autopilot system must move the control surfaces continuously and at rapid rates in order to counteract the wave-induced disturbances. In some seas, it may not be desirable to platform, and here the control system will have to permit some vertical action. This suggests not only a wave-height sensing device, but also inputs to the autopilot from accelerometers. Roll control will require additional displacement, velocity and acceleration inputs.

✓ Supercavitating Regime Problems: These are considered most important. Systematic experimentation on the effect of geometric characteristics of foils is lacking. There is no corresponding airfoil data that is useful. In very high speeds or large angles of attack required for true cavity flow, the cavity would probably have to vent to the atmosphere, either through tip vortices or down a strut. The mechanics of ventilation are not well understood and require research starting with the basic physics of the phenomenon.

A simplified theory of hydroelastic instabilities has been developed, but experimental data is required.

Advances are sorely needed in materials in order that the requirements for very high strength, erosion and corrosion resistance, toughness, good fatigue life, etc. may be set.

In the supercavitating or superventilating range a take-off may well be critical. Feasibility studies have shown that for very high speed craft, take-off thrust requirements are incompatible with top-speed requirements. Means for achieving take-off at lower speeds need special attention.

Foil smoothness is vital to good performance. Tests indicate that paint is likely to peel off at high speeds. One system under study employs cathode protection. High current densities are applied when the boat is motionless in the water. This plates out a combination of magnesium hydroxide and calcium carbonate on the foils. The idea is that the fouling will attach to this rather soft coating and slough off at reasonably low forward speeds. A minimum value of current density is applied at all times to eliminate corrosion.

✓ Current Status: An extensive research and development program is directed toward a large experimental subcavitating hydrofoil ship of about 300 tons displacement, and a small superventilating hydrofoil boat (about 15 tons) to be in operation by 1963.

Shark Form Craft

This is, in effect, a near-surface craft with a relatively large strut piercing the surface. The shape and location of this large strut should be such as to cancel as much of the main hull's wave resistance as possible, and reduce the exciting forces and moments due to sea action. This concept, explored to some extent by the Germans during World War II, holds promise of high speeds and small motions.

Some Problems:

✓ Submerged hull must be located well below the free surface in order to minimize wave-making resistance and the exciting forces of the sea. In common with the near-surface craft, the shark form requires power plants of less specific density than currently available -- in order to attain the most promising speed-power advantages.

✓ Topside weight which can be carried is limited by low transverse stability. With very little waterplane, stability must be attained by keeping the center of gravity below the center of bouyancy. This is not easy in a form such as this, in the face of the demand for topside locations for equipment. The shark form, in common with ground-effect craft, also has the problem of running trim in calm water. Large control surfaces, and an autopilot, may be required.

Spar Ship

This was designed to be an inexpensive and effective sonar ship, in which speed was not an important parameter. The principal idea was to submerge the sonar dome as deep as possible on a surface ship. This led to a ship having a vertical distribution of displacement, rather than horizontal. According to feasibility studies, speed was low, as expected, but model tests showed that the vertical location of the center of resistance varied considerably with speed -- causing substantial changes in running trim. The form was also highly directionally unstable. Calculations indicated supercritical heave motions in practically all seas. The practicality of the concept is questionable, but not impossible. One problem would be taking such a ship in and out of harbors. The only apparent way would be to provide ballasting arrangements to permit the ship to be brought to a horizontal position.

Catamarans

Sea-keeping characteristics of planing catamarans have been looked upon favorably, and a testing program is underway at the David Taylor Model Basin near Washington, D. C. This configuration has promise of planing in relatively high waves, a characteristic that has not been attained with conventional planing craft. Structural problems will require careful attention.

Hulls of Minimum Wave-Making Resistance

One optimum form in theory would be a "coke-bottle" waterline. If model tests check the theory, feasibility studies of practical ships will be made.

Devices to Increase Performance of Conventional Ships

✓ Boundary layer control might be used to reduce frictional resistance to about 15 percent of its normal amounts. The objective would be to maintain laminar flow by sucking off the boundary layer at various places along the length of the body. It is not known how much power would be needed for suction, or how the clogging of pores by marine life could be prevented, or -- if slots are used -- their best location, shape and size.

✓ Enclosing the body by a gas is another possibility which, ideally, would reduce frictional resistance to about 1 percent of its normal amount. A major problem is the stability of the gas film, since experience has shown that resistance is only slightly decreased if the gas goes into bubble form.

Devices to Increase Performance of Conventional Ships (Continued)

✓ Coating that absorbs the energy in perturbations in the water is another possible means of increasing speed. One new theory indicates that a coating could be devised to maintain laminar flow up to very high Reynolds Numbers.

Conclusion: "These three methods of reducing frictional resistance may have application to midget submarines and possibly to larger craft, but theoretical and experimental evidence to substantiate claims and predictions is yet to be acquired. These methods appear to have more promise in the relatively low range Reynolds Numbers, than at the high Reynolds Numbers at which large ships and submarines operate."

Increased Efficiency of Propulsion Devices might also contribute to higher speeds, but no dramatic improvements in this area appear to be in the offing. However, a number of promising new types of devices are under study and some older ideas are being refined. These include: Supercavitating or superventilated propellers; pump jets; kort nozzles; cycloidal propellers; oscillating fin and two-phase flow jets.

Control devices which hold promise for competing with the highly efficient, standard ship rudder are also of interest. One of these, the cycloidal propeller, is well-known. Another is the jet flap, currently under study for aircraft. Design data, including mass flow vs. rudder effectiveness are being obtained.

Another competitor for the rudder is the ring airfoil, developed originally for aircraft. Preliminary results indicate excellent control characteristics.

Devices for minimizing motions have been under study for some time. For roll control, gyrostabilizers, active fins and Frahm tanks are available. Re-examination of the latter, in recent years, has shown that by good design passive tanks can be quite effective in reducing roll. Considerable effort has also recently gone into pitch stabilizers. Fixed fins at the bow can significantly reduce pitch. Under study today are moving fins at bow and stern, and flapped ducted propellers.

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* Deep Diving Submarines pose difficult but not insurmountable problems according to another report, prepared by E. E. Johnson, David Taylor Basin, U. S. Navy, Washington 7, D. C., details of which are classified. Among non-classified conclusions:

Exploratory research on structural models of deep-diving vehicles indicates that marked improvements in depth capability can be attained without increase in weight by the use of radically new design concepts. These new concepts include sandwich construction, in which two concentric cylinders of steel are separated by a load-carrying core, and composite construction, in which a high strength nonweldable material is encased in a weldable jacket. The use of new materials, such as titanium and reinforced plastics, has also been investigated but many new problems must be solved before these can be used in an actual submarine.

* Deep Sea Research Vessel Engineering Study has been completed, according to F. Pierce, U. S. Naval Ordnance Test Station, China Lake, Calif. The vehicle would have "unlimited" depth capability, and would carry a crew of three on 100 mile cruises in the deep sea. The vessel is a streamlined, powered bathyscaphe with six knots maximum speed, and three knots for cruising. The vehicle has a displacement of 90 tons and is 70 feet in length. Stable buoyancy would be achieved by using non-flammable aqua ammonia instead of gasoline. Equipment would include sonar, a manipulator, bottom samplers, corers and various photographic, hydrographic and oceanographic equipment.

RESEARCH CHECKLIST

- HEAT RESISTANT FIBER: The Air Force has issued an encouraging progress report on HT-1, a fiber which may be of value in tires for the B-70 bomber, in decelerator parachutes for space capsules, personnel parachutes and packs and in military clothing. The Air Force states that, unlike nylon, HT-1 will not melt, fuse or burn at high temperatures. Even at its carbonization point of 840° filaments remain intact. In addition, HT-1 retains approximately 100 percent of its original strength and stretchability when subjected to strong gamma radiation at room temperature. In addition to its fabric-type applications, temperature resistance and decomposition characteristics will be evaluated as a promising reinforcement for ablating plastics and re-entry heat shields.

  (HT-1 development by the E. I. duPont de Nemours Co., Wilmington, Delaware reported by Materials Central, Aeronautical Systems Division, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio)

- CARBON-HYDROGEN ANALYZER: Studies by Bell and Howell Inc. for the Air Force have resulted in development of a rapid electro-analytical method for the determination of carbon and hydrogen in non-metallic organic compounds containing carbon, hydrogen and oxygen. A novel combustion technique was employed which can be applied to the solid, liquid or gaseous state of aggregation. Goal of the research was a comparatively low-cost, reliable and compact instrument capable of accurate determination.

  (Report dated September, 1960 now available, as WADD Technical Report 60-415 through military channels or as PB 171 409 at 75 cents from OTS, U. S. Department of Commerce, Washington 25, D. C.)

- ULTRASONIC FLAW DETECTION: Army Ordnance is working a novel technique which may simplify the use of ultrasonic waves for the detection of hidden flaws and determination of the microstructure of materials. The method may make possible a single operation for obtaining ultrasonic attenuation and frequency relationship. This is done by employing ultrasonic pulses which contain energy over a wide band of frequency, together with a spectrum analyzer to detect the frequency dependence of ultrasonic attenuation. Eventually, the work may lead to an advanced flaw detection system which could obtain information on defect size and configuration through contour or spectrum analysis of the echo received from a discontinuity.

  (Details available in Watertown Arsenal Technical Report 830.5/1 ((PB 171 186)) available through military channels or at 50 cents from OTS, U. S. Department of Commerce, Washington 25, D. C.)

- IRRADIATION OF X-RAY FILM: Studies by the National Bureau of Standards in the successive irradiation of x-ray film may lead to a better understanding of the nature of the photographic latent image, and may also be of interest in industrial and military applications of photographic dosimetry of x-ray and gamma radiation. The results of the irradiation study show that the shapes of the density-versus-exposure curves resulting from dual exposures are essentially the same as those of the curves resulting from the second exposure alone.

  (Write National Bureau of Standards, Office of Technical Information, Washington 25, D. C. for further details of Successive Irradiation of X-Ray Film)

□ LOW-COST FOUR STATION SYSTEM FOR TRACKING SPACE VEHICLES: Augmentation of the elaborate tracking research systems now in use is required through the use of simple, low-cost systems. NASA's Langley Research Center has devised such a system which calls for a low-power CW beacon in the space vehicle and at least four Doppler receiving stations on the ground. The principal advantage of the system is that the transmitter frequency does not need to be accurately known. In a preliminary design analysis of this system NASA has discussed the proper location of the receiving stations, rules for avoiding infinite errors, error charts for ideal station locations, influence of the index of refraction, position error formulas and the accuracy required in the measurement of Doppler frequencies. It is estimated that the system is capable of determining space vehicle position within 1,000 ft. at a range of 200 miles.

(NASA Report TN D-748, "Analysis of a Four-Station Doppler Tracking Method Using a Simple CW Beacon", available from National Aeronautics and Space Administration, Attn: CODE BID, 1520 H Street, N. W., Washington 25, D. C.)

□ MECHANICAL PROPERTY RECOVERY OF IRRADIATED MATERIALS: The mechanical property recovery of various irradiated materials through annealing has been summarized by the General Electric personnel operating the Knolls Atomic Power Laboratory for the AEC. While the fundamental mechanisms for the annealing of radiation damage have not yet been precisely defined this G.E. report interprets the available test data in terms of a specific mechanism. Under this interpretation radiation damage is a two-stage process involving source hardening and lattice hardening caused by clustered interstitials or vacancy clusters. Proper annealing requires transmitting enough energy to the material to close the defects through self-diffusion. The G. E. group believes their interpretation fits a wider number of materials damage cases than any other theory presently available. The group has also defined a recovery parameter for metals which is a function of the self-diffusion activation energy and the annealing temperature.

(AEC Research and Development Report KAPL-2103, "Radiation Effects upon the Recovery of the Mechanical Properties of Metals", available through AEC channels or at $1.00 from OTS, U. S. Department of Commerce, Washington 25, D. C.)

□ SPECIAL PURPOSE ANTENNAS: The National Bureau of Standards has designed and constructed special-purpose antennas for investigating micropulsations in the earth's magnetic field, and their possible relation to unusual solar or magnetic activity. The 6½ ft. loop antennas contain 32,000 turns of nylon coated copper wire. They are expected to provide useful information on ionospheric disturbances arising from extraterrestial sources which may affect radio communications.

(Project directed by W. H. Campbell, Central Radio Propagation Laboratory, National Bureau of Standards, Boulder, Colo.)

□ DEVELOPMENTS WITH IRON-ALUMINUM-BASE ALLOYS: Progress has been made in improving the ductility of iron-aluminum alloys, which offer an alternative to titanium for various applications. The ferritic type of iron-aluminum alloy has generally been abandoned for the austenitic type to obtain the improved ductility. Austenitic alloys have been developed which exhibit nearly optimum high-temperature properties and oxidation resistence which are comparable with commercial stainless steels. The National Research Corporation, Ford Motor Co. and the Crucible Steel Co. have been most prominent in working with this type of iron-aluminum alloy. A complete report on research and development activity with Fe-Al alloys has been prepared by the Defense Metals Information Center.

(DMIC Memorandum 82, "Review of Developments in Iron-Aluminum-Base Alloys", available to Government agencies, contractors, subcontractors and their suppliers from Defense Metals Information Center, Battelle Memorial Institute, Columbus, Ohio)

PUBLICATION CHECKLIST

- COORDINATION OF INFORMATION, an excellent review of the problems of coordinating information on current scientific research and development supported by the U. S. Government. Systems now in existence, the report states, are "A hodge-podge--overlapping, underplanned, under-nourished and under-used." Amen. 285 pages. (Write Committee on Government Operations, Subcommittee on Reorganization, Room 162, Old Senate Office Building, Washington 25, D. C. for Report--Coordination of Information)

- NUMERICALLY CONTROLLED MACHINING OF FORGING DIES, a fine review by the Wyman-Gordon Co. for the Air Force, unfortunately delayed in distribution by Government red tape. 71 Pages. (AMC Technical Report 60-7-667a ((PB 171 378)) available through military channels or at $2 from OTS, U. S. Department of Commerce, Washington 25,D. C.)

- IMPLICATIONS OF SPACE ACTIVITIES, a thought-provoking report by the Brookings Institution on the implications of space research in such fields as satellite communications, weather prediction, technological by-products, etc. 272 Pages. Single Copies Free. (Write Committee on Science and Astronautics, New House Office Building, Washington 25, D. C. for "Proposed Studies on the Implications of Peaceful Space Activities for Human Affairs")

- MEASUREMENTS AND STANDARDS IN PLASMA PHYSICS AND ASTROPHYSICS, a detailed review of programs at the National Bureau of Standards in the field of hot gases. Includes a selected list of technical papers on this subject. 33 Pages. $1. (Write OTS, U. S. Department of Commerce, Washington 25, D. C. for NBS Technical Note No. 59)

- PREPARATION OF FINE-GRAIN EMULSIONS, a British review of problems and experiences in the small-scale preparation of fine-grain (colloidal) photographic emulsions for microphotography. 18 Pages. 25 Cents. (Write British Information Services, 45 Rockefeller Plaza, New York 20, N. Y. for Notes on Applied Science, No. 20)

- BENDING METHODS FOR STAINLESS STEEL TUBING, a review of the applications and limitations of various methods of bending the stainless steel tubing used in modern aircraft to transmit gases and fluids. Emphasizes some special equipment developed by the Boeing Aircraft Company, and soon to be marketed commercially. 44 Pages. Single Copies Free to Government Agencies, contractors, subcontractors and their suppliers. (Write Defense Metals Information Center, Battelle Memorial Institute, Columbus 1, Ohio for DMIC Report No. 150)

- IRRADIATION EFFECTS, a technical study of various irradiation effects on several transistors, solar cells resistors and condensers to be used in the space radiation environment. 28 Pages. Single Copies Free. (Write National Aeronautics and Space Administration, ATTN: CODE BID, 1520 H Street, N. W., Washington 25, D. C. regarding Technical Note D-718)

- TRITIUM EXCHANGE LABELING, a report on the preparation of tritium-labeled organic compounds for use in studying the role of certain gasoline constituents in gum-forming mechanisms. 17 Pages. Single Copies Free. (Write Publications-Distribution Section, U. S. Bureau of Mines, 4800 Forbes Avenue, Pittsburgh 13, Pa. for Report of Investigations No. 5717)

- LABORATORY TESTS FOR EXPLOSIVES, a new edition of a manual outlining standard laboratory procedures for determining the sensitivity, brisance and stability of high explosives, primers, pyrotechnic compositions and propellants. 42 Pages. (Technical Report FRL-TR-25 ((PB 171 326)) available through military channels or at $1.25 from OTS, U. S. Department of Commerce, Washington 25, D. C.)